The Problem of CRT Resolution

or

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High resolution cathode ray tubes for the system designer

by

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ABSTRACT

In this day when everybody is talking about solid state devices, it appears that there is one vacuum tube component which is not likely to be replaced for some time. This is the cathode ray tube. It is the prime transducer of information from the intangible electrical medium to human beings and is also widely used for film scanning and recording. The cathode ray tube today is fast, versatile, accurate, and is capable of demonstrating a resolving ability which challenges optical lenses.

The purpose of this paper is to discuss the category of cathode ray tubes which are capable of resolving detail which is beyond that which the human eye can appreciate. This is the class of tubes used primarily for scanning of film or recording on photo sensitive materials.

High resolution gun designs will not be discussed. The major purpose here will be to give the designer who is interested in high-resolution cathode-ray tube systems a guide for use in intelligent selection and practical operation of these tubes.

Applications

Below are listed some of the applications to which high resolution tubes are being put today:

- Side looking radar processing and recording
- Atomic particle track scanning
- Document scanning
- Inspection of film recordings
- Picture recording, satellite
- Infra-red recording
- Cell counting
- Densitometry
- Film ba[illegible] large screen displays
- Scanning [illegible]or simulators, radar [illegible]
- Scanning for photo interpretati[illegible]
- Character recognition
- TV scan[illegible]ing
- Video recording
- Computer controlled scannin[illegible]
- Document storage and retrieval.

Before selecting and applying high resolut[illegible] ray tubes to a particular system, caref[illegible] attenti[illegible] given to the subject matter in various sections of the[illegible]ing article covering the tube's geometrical outlin[illegible] phosphor face, and the electronic driving equipmen[illegible]

Resolution

The first question asked about high resolution t[illegible] What is the spot size? The claims of manufact[illegible] impressive in this respect. By [illegible] data sh[illegible] appear [illegible]

the market with rated spot sizes of under one one-thousandths of an inch (0.001 in.) or, as it is referred to in the industry, 1 mil.

The system designer then figures that he has 1000 elements to the inch, extended over 4 in. of screen area on a 5 in. tube, so he can realize over 4000 elements on a trace across the tube. Unfortunately, it is not as simple as that. There are several factors which will modify the ideal number to a more useful resolution figure. These are:

(1) The method by which the resolution is to be evaluated
(2) The degree of response or modulation depth required for a given resolution
(3) The spot size at the light output (hence, beam current) required for the application
(4) Deflection defocusing.

Measuring method and modulation depth are tied together. A number of methods are available for measuring resolution. The shrinking raster method is common, mostly because it is easy to do. A raster with a known number of lines is generated on the tube face and the vertical size is decreased until the lines disappear, or merge. The height of the raster is measured at this point and the measurement is divided by the number of lines. The method is valid as long as the beam is not distorted so that the spot is wide along the length of the raster lines and the evaluator is aware of what level on the spot light distribution curve he is measuring.

Generally, the spot profile will be a gaussian curve. If the measurement at a particular level is known, those adept at mathematics can calculate their system resolution.

One of the better methods of measuring resolution is to actually make a picture of the spot profile[1], as shown in Figure 1. This is done by moving the spot past one or two slits which are small compared to the spot. A phototube on the other side of the slit will display the spot profile on an oscilloscope. There is at least one slit analyzer now on the market for measuring cathode ray tube resolution.

Another method is to scan the spot while it is being modulated with superimposed sine waves in such a way that the output of a phototube looking at the spot modulation through a small slit will produce a measurement of spatial frequency response in cycles per unit length.

Several other variations of these methods are available and, of course, one can always measure the spot directly with a high power microscope. This latter method is probably the least recommended since it is difficult to determine where the spot edge is.

FIGURE 1: Spot profile taken with a CELCO two slit analyzer using slits to produce 0.0005″ per centimeter.

[1] M. C[illegible]ntine, Two-Slit Spot Me[illegible]rement, 7th Nati[illegible]ym-[illegible], Soc[illegible]or Information Display.

Remember that in film recording systems, various film emulsions will "see" the spot profile at different levels.

In the final analysis, the tube which works best in the system is the one to buy and, if possible, different tubes should be tried.

Spot size at a particular light output is most important for scanning tubes where a large amount of light output is usually required. Electrons repel each other and as the number of the electrons in the beam is increased by increasing the beam current, the beam size, and consequently, the spot size, grows. The resolution given on most manufacturers' data sheets is at beam currents of one microamp or less. Incidentally, it is not always a good idea to reference spot size to beam current since some manufacturers employ anode aperturing where the aperture is internally connected to the anode. Because of this, it is not possible to accurately measure how much current is actually striking and exciting the phosphor.

Deflection defocusing is caused by:

(1) The change in electron path length with deflection angle, thus requiring a different focus field strength for each radial distance of the spot from center of the screen
(2) The non-uniformity of deflecting fields and electron motions
(3) The fact that when a roughly cylindrical beam meets a flat phosphor screen at an angle, the resulting figure is an ellipse.

The ellipse effect is quite negligible compared to change in path length and field non-uniformities. Problems with the latter two items can be compounded by astigmatism in the beam. The change in path length is usually handled pretty well by use of dynamic focus correction and relatively simple driving circuitry which computes the radial distance of the beam from center of the face and introduces the proper amount of focal length correction.

Field non-uniformity with beam astigmatism is the most difficult to handle. It is perhaps most expedient to incorporate a high quality deflection coil in the system. These high quality yokes are expensive, but they are designed to produce a uniform field which will minimize the defocusing effects inherent in the deflection coil. The added expense of a high quality yoke is usually negligible compared to the system cost. Static and dynamic astigmatism correctors are also available, but are some times difficult to drive with the proper waveforms.

Resolution and Basic Tube Geometry

Disregarding the intrinsic capabilities of different electron guns, there are certain basic guide lines to follow in selecting the general outline of a high resolution tube.

Figure 2 depicts a simple optical ray tracing diagram. In this case, the object A is the so-called cross-over point in the electron gun. The object A appears as the image B on the phosphor screen. The lens C is analogous to the focus coil. It is apparent that as the lens C is moved toward B, and the strength or focal length of the lens is readjusted, B will become smaller.

This is according to the formula:

$$\frac{x}{u} = \frac{y}{v}$$

where

x = object size
y = image size
u = object distance
v = image distance

FIGURE 3: Cathode ray tube with a sub-mounted screen to reduce halo.

aluminum coating — if any, and the phosphor deposition method. As the screen is made thicker, it will reach its peak efficiency at a higher anode voltage. A thin screen at too high a voltage would allow the electrons to go on through without giving up maximum energy to the phosphor. The aluminum coating, if any, will affect the electron's energy and, of course, contribute to the light out the front of the tube through optical reflection.

With optimum anode voltage, various screen deposition methods and phosphor treatment will have a large affect on spot size. Larger particle sizes tend to have more efficiency and, in a thick layer, will produce the most efficient screen. Of course, this screen will not have good resolution. On the other end of the scale are evaporated phosphor techniques which produce very high resolution screens with poor light output. The high resolution tube manufacturer must compromise screen thickness and particle size to achieve the highest light output possible consistent with desired resolution.

Contrast

Contrast on a cathode ray tube, a typical example of which is shown in Figure 3, is degraded by spot halo which is caused by internally reflected light trapped inside the faceplate.[4] In flying spot scanner applications, this halo decreases signal-to-noise ratio and in recording applications, it reduces contrast.

There are five ways of attacking the problem:

(1) Decrease the transmission of the faceplate
(2) Use a transparent phosphor
(3) Increase the thickness of the faceplate
(4) Make the faceplate very thin
(5) Use a fiber optic faceplate.

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The solution to the halo problem, which is actually finding its way into some systems, is to decrease the face thickness. Since a thin glass face cannot support the vacuum load, the phosphor is deposited on a very thin plate which is sub-mounted behind a regular thick faceplate. The disadvantage to this approach is the relative fragility of the sub-mounted glass which is usually in the neighborhood of only 0.020 in. thick.

Use of a fiber optic tube is probably the best, and also the most expensive, solution. The expense is particularly unattractive for larger tubes.

Phosphors

Although there are a few variations on the market, the two most popular phosphors for scanning and recording are P16 and P11, respectively. Although the output of P16 is in the ultra-violet and it generally ages under excitation to a lower light output,[5] its overall characteristics seem to continue to hold an edge over other newer fast decay phosphors. It would appear that P16 aging is a function of current and time only and it thus looks desirable to run P16 at higher anode voltages in order to obtain longer tube life. P16 is also used to expose UV activated dry process films such as photochromics[6] and Kalvar. Some effort is being directed toward increasing the efficiency of P16 for this use.

P11 makes a good, fine grain screen but it is more susceptible to contamination and when loaded too heavy, will saturate. The decay time of P11 also varies with loading.

For color scanning, P24 is used because of its broad spectrum and relatively fast decay.

Phosphor Blemishes

On a typical 5 in. tube, there are around 14 million, 1-mil square elements. In many applications, it is important that all, if not a very large percentage, of the phosphor area be free of blemishes that would affect performance on the system. Typical manufacturer's specifications divide the screen into quality areas — usually three concentric circles. The area near the center is the cleanest. Blemishes are usually defined as bright specks, dark specks, or color specks and their size is taken as the largest dimension or, often, a ratio of dimensions is specified. Inspection methods include visual observation, and actual scanning of the entire screen using a phototube with a sweep frequency that allows the phosphor to decay from element to element to a specified bandwidth. The size of the speck shows up as the height of a spike on the oscilloscope used to monitor the output of the phototube. This method is also used to evaluate phosphor noise.

Phosphor Noise and Uniformity

Phosphor noise is caused by variation in light from particle to particle or groups of particles. The noise usually is inversely proportional to spot size and, as the spot is run through focus by varying the focus strength, the noise will hit a peak.

Different screen deposition methods will produce varying amounts of noise. Settling of particles which are not classified or sized will usually produce the noisier screen. Phosphor noise can be measured by placing an appropriate phototube in front of the cathode ray tube on which is running a single line trace electronically or physically

[4] [illegible] [illegible]d M[illegible]ton, Television, 2nd E[illegible]. Wiley, 1954, pages [illegible]

[5] Pfahnl, Properties of Fast-Decay Cathode Ray Tube Phosphors. *Bell System Technical Journal, January, 1963.*

[6] *Dorion, Roth, Stafford, Cox,* CRT Phosphor Activation of Photochromic Film.

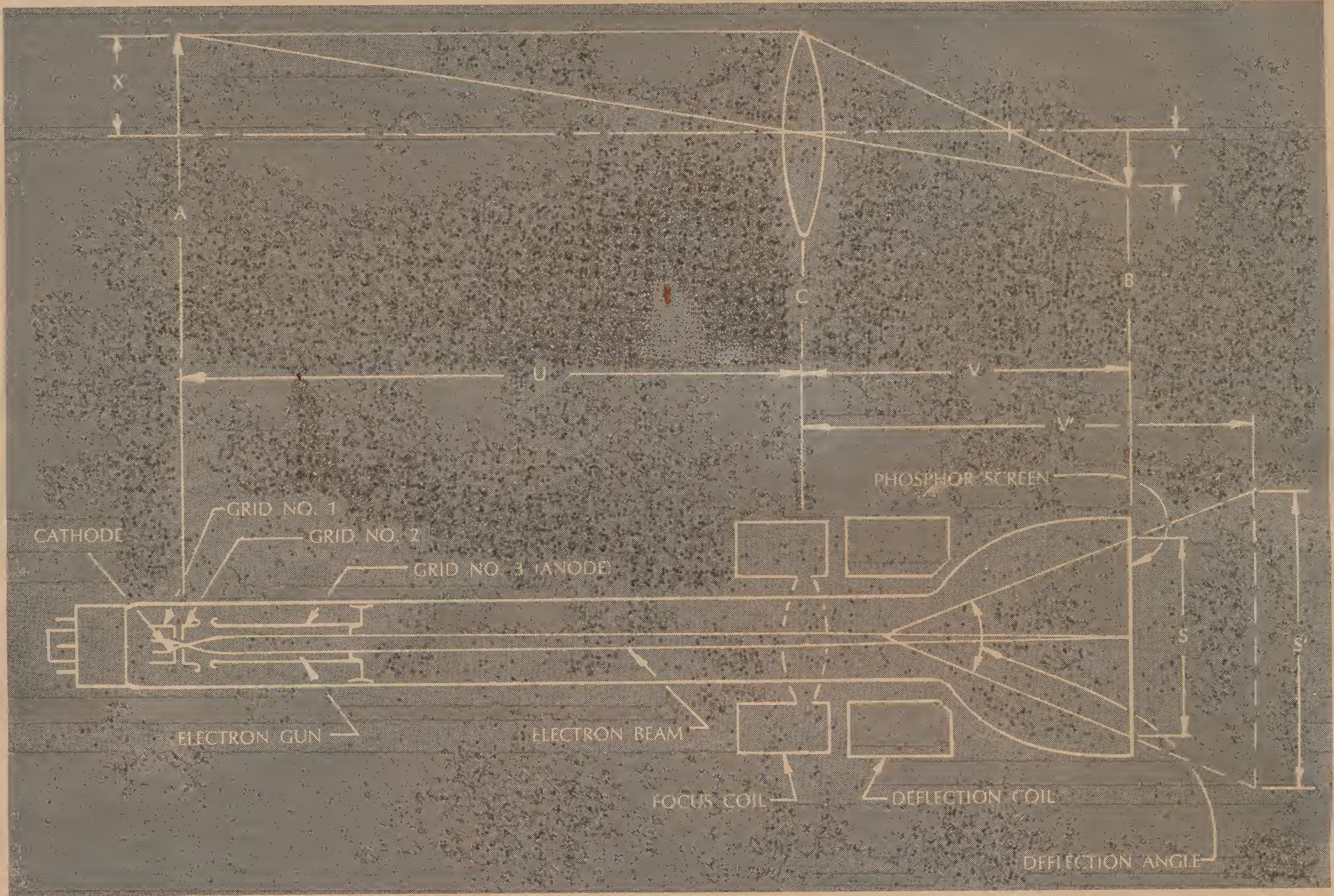

FIGURE 2

Thus, as the focusing element is moved closer to the screen, the spot size gets smaller. Obviously, for best resolution for any cathode ray tube, the focus element should be as close to the screen as possible without picking up stray coupling from the deflection coil.

For practical cathode ray tube designs, it is not possible to take full advantage of this demagnification. First of all, there is a requirement for a given trace width or screen area on the face of the tube. So, for a given trace width, as distance v is shortened, the deflection angle for the required screen area becomes larger, thus taxing available deflection power and giving rise to non-linearity and deflection defocusing problems.

Then why not increase distance u ? This is limited because the longer beam path length allows too much spreading in the beam and it has been shown that this results in aberrations in the beam.[2]

Also, one must bear in mind that the electrons do not act precisely like light rays. Some are traveling at different velocities and some are traveling sideways in the beam. Each electron also repels its neighbors thus setting a practical limit on how tight the beam bundle can be for a given anode voltage.

All of the foregoing indicates why, generally, the beam size seems to grow with the tube size. That is, if the deflection is held constant and the scan distance s is increased to s', then distance v is increased to v', thus making the optical reduction ratio more unfavorable. Also, one can see the trade-off which exists between deflection angle, screen size, and the resolution which can be achieved at the center of the screen.

PHOSPHOR SCREEN

Light Output

The question most often asked after "What is the spot size?" is "What is the light output?" For direct view applications, this is most commonly expressed in foot-lamberts since this unit is oriented to human vision. Ways of measuring include foot-lambert meters, such as the Weston 759, and spot brightness meters. The latter is preferred. When using the foot-lambert meter, it is well to specify proper use of the hood or cylinder which spaces the sensor from the face of the cathode ray tube. With the sensor against the tube face, without the hood, the reading will be approximately π times high[illegible] th[illegible].

For recording or scan[illegible] tubes interest is radiant po[illegible] gross estimates, foo[illegible] power if the lumino[illegible] Information which is available on phosphor [illegible] be misleading, especially for high res[illegible] phor e[illegible] the screen is usually thin. Available figures [illegible] take into account the effect on efficiency [illegible] various deposition methods or the portion [illegible] actual power radiated out the front of a cathode ray tube. Actual phosphor efficiency in radiated watts out the front of the tube, per watt of excitation, will vary considerably in different tubes as a function of anode voltage, screen thickness, the

2 *Soller, Starr and Valley, Cathode Ray Tube Display. MIT Radiation Lab Series, No. 22, McGraw Hill, 1948, page 97.*

3 *Leo Deiser, Energy Transfer from CRT to Photo-Sensitive Media. Information Display, September-October, 1965*

[illegible] iner Ph[illegible]

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[5] *Pfahnl,* Properties of Fast-Decay Cathode Ray Tube Phosphors. *Bell System Technical Journal, January, 1963.*

[6] *Dorion, Roth, Stafford, Cox,* CRT Phosphor Activation of Photochromic Film.

blanked for half the trace length. The noise is observed as "grass" on the step produced when the phototube output is observed on an oscilloscope and its percentage of the step can be measured. Select a sweep frequency slow enough so that phosphor decay will not mask the noise.

Phosphor non-uniformity shows up as a gradual change in light output or color over the entire screen. This is sometimes called shading and is easily observed with a phototube and oscilloscope.

The Faceplate

The cathode ray tube faceplate is actually part of the optical system and its quality should be commensurate. The faceplate glass is generally specified for optical quality with minimum seeds, bubbles, chill wrinkles, and uneven surface. In optical systems employing low f number lenses, the depth of focus is very short, thus requiring a high degree of flatness in the faceplate.

Screen Size

Although, as pointed out, spot size tends to grow with tube size, there is some net gain in resolution with the larger tube sizes. Aside from resolution, other advantages to larger screen sizes include reduced phosphor noise and reduced phosphor loading. Of course, the larger sizes are more expensive and usually require a more expensive lens.

For a given size at the film plane, the spot will cover more area on the phosphor plane with a larger cathode ray tube, than with a smaller one. Since phosphor noise is inversely proportional to spot size, noise with the larger tube will be less. Also, with a larger cathode ray tube, more phosphor area is utilized so that for phosphors which age, like P16, tube life will be longer.

Because of vacuum loading and the requirement for a truly flat face dictated by optical systems, the limit on tube size appears to be around 9 or 10 in. in diameter.

Stray Emission

Because of the intense electric fields which exist in a cathode ray tube gun, it is sometimes possible that there will be field emission from microscopic particles or surface irregularities in the lower electron gun structure. Sometimes there will be secondary electron emission from apertures in the gun. In the latter case, the secondary or "ghost spot" will be cut-off when the primary beam is cut-off. In the former case, a spot can be seen when the high voltage is on, regardless of electron gun bias level.

Existence of stray emission can, of course, have an adverse effect on cathode ray tube recording or scanning performance. Careful examination of the cathode ray tube screen in a darkened room will usually reveal this defect. Most cathode ray tube manufacturers have methods for eliminating this condition, should it arise.

Also, in the case of photo recording systems, don't forget that the glow caused by the cathode heater can sometimes fog the film.

Fiber Optic Tubes

Since fiber optic bundles have become available for sealing onto cathode ray tubes, many system designers are turning to high resolution fiber optic tubes to solve unique problems. The largest number of applications are those involving relatively insensitive dry-process films and high speed recording on conventional film.[7]

Up to the phosphor screen, the same comments contained in the rest of this article apply. The fiber optic plate itself and how it affects resolution, light output, etc., is discussed in the following paragraphs.

Generally, the principal advantage of a fiber optic face is additional light. The film to be scanned or exposed is laid directly on the tube face, thereby capturing a much larger percentage of the phosphor light than can be realized through a lens. The light gain over a typical conventional optical system is approximately 30. Because of this increase in light transferred to the film plane, it is possible to:

(1) Expose relatively insensitive dry-process films
(2) Increase the writing speed for high speed trace recordings
(3) Reduce beam current for conventional film emulsions, thus resulting in better spot size
(4) Reduce anode voltage, thus decreasing deflection power and total system power consumption.

Additionally, elimination of the lens makes the optical system more compact. Disadvantages are that it is no longer possible to use optical reduction to achieve a better spot size at the film plane, and the higher cost of the tube, although the latter disadvantage can be offset by the lens cost.

The numerical aperture, the type of glass, and the fiber size used in construction of the fiber optic plate determines the transmission efficiency and resolution of the plate.[8, 9] Plates are readily available for sealing on to cathode ray tubes with a numerical aperture of .66 and 8μ pitch fibers. Limiting resolution for this kind of plate is around 60 1p/mm (0.3 mils). Plates with a limiting resolution of 100 1p/mm are available. The quality of fiber optic plates has improved markedly in the last year or so to the point where blemishes can be controlled well enough for most system applications.

Another use of fiber optic plates is for intrinsic correction of spot position linearity on the face of the cathode ray tube by curving the inside of the plate to the radius of deflection.[10] Experience so far has shown that electronic correction is usually a better way to go from the standpoint of cost and flexibility.

Fiber optic tubes may also be used with conventional optical systems or for direct view work where it is desired to enhance contrast by elimination of spot halo. On direct view displays, which require an overlay, parallax is also eliminated.

ELECTRONIC EQUIPMENT

General

The cathode ray tube can be no better than the equipment that drives it. Therefore, a high quality cathode ray tube will require high quality electronic equipment if the maximum yield is to be realized.

The major cathode ray tube [illegible] components are:

(1) High vo[illegible] supply [illegible] tubes
(2) [illegible] suppl[illegible]
(3) Focus coil and [illegible] fo[illegible]
(4) Deflection coil a[illegible]

[illegible] availab[illegible] on [illegible]

The High Voltage Supply

Generally, the an[illegible] de voltage should [illegible] hes[illegible] sible, taking into consideration:

(1) Tube rating [illegible] ulated
(2) Deflection power
(3) Environment

[7] Fred L. Katzman, Improving Ultra Fast Transient Recording Using Fiber Optic Cathode Ray Tubes. *Electronic Instrument Digest*, October, 1966.

[8] J. Wilbur Hicks and Paul Kiritsy, Fiber Optics. *Glass Industry*, April [illegible] May, 1962.

[9] Mosaic Fabrications, B[illegible]tin Series 100.

[10] Litton type L-4198 Cathode Ray Tube.

(4) Possible X-ray problems.

Because electrons repel each other, the smaller spot size will be achieved at lower beam currents. This means that if the user can run the tube at 30 kv instead of 20 kv the current required for the same brightness will be less, resulting in some reduction of the spot size, as long as the screen thickness is such that efficiency is not lost. It is also true that at higher voltages there is less tendency for the beam to spread in the first place due to the shorter time each electron remains in the field of its nearest neighboring electrons. A further advantage to higher voltages is that the decrease in beam current for a given brightness adds to the tube life, especially in the case of P16 phosphor.

It can now be seen that there is a trade-off of resolution with deflection power. For, as the anode voltage is raised, the beam becomes "stiffer" and requires more power in order to be deflected through a given angle. The deflection could be decreased to make up for a higher anode voltage but then, as previously pointed out, there may be a sacrifice in spot size.

Fortunately, new high power deflection amplifiers make it possible to use higher anode voltages while new insulating materials and potting techniques have reduced the hazard of shock.

High voltage supply regulation, hum and ripple specifications are very important for high resolution displays. Supposing a stationary focused spot is located on a cathode raye tube screen. Suppose further that this spot is deflected off center by several inches. Now, if the high voltage control is varied, the spot will be seen to move in toward the center of the tube if the anode voltage is increased, and out toward the edge if the voltage is decreased. Supposing now that the high voltage control is moved back and forth at a high frequency. A point will be reached where one will no longer be able to detect spot movement, but the spot will appear larger.

The spot will look larger as governed by the following formula:

$$\frac{dV}{V} = 2 \text{ Cos}^2 \theta \ \frac{dD}{D}$$

where

D = distance of the spot from the center of the tube
θ = deflection angle of the spot (from center)
V = accelerating voltage

This formula can be used to calculate required high voltage supply hum and ripple characteristics for maximum allowable spot growth due to this effect. A typical example would be the allowable high voltage hum and ripple for a 5-in, 40° high resolution cathode ray tube.

The following assumptions are made:

(1) The spot size at the center of the screen is 0.001 in.
(2) Allowable growth due to the high voltage supply is 10% or 0.0001 in [illegible] screen edge
(3) [illegible] or 40° total angle deflection is
dec [illegible]
or [illegible]
th [illegible]
with [illegible]
bec [illegible]

$$\frac{dD}{D}$$

dV = [illegible]

FIGURE 1: [illegible]

$$= \frac{2 \text{ Cos}^2 20^\circ \times 10^{-4} \times 25 \times 10^3}{2.125}$$

$$= 2.079 \text{ volts peak-to-peak}$$

[illegible] ain for allowable spot position error due to

the high voltage supply, the formula can be used to calculate regulation and stability requirements for display linearity.

The Electron Gun Supply

In a tetrode type gun, the gap between the No. 2 grid and the anode forms an electrostatic focus lens that is part of the tube's electron optical system. For this reason, the G2 voltage supply should be reasonably well regulated. Changes in the G2 voltage will also cause changes in the drive characteristics of the gun thus modulating the beam current. In some gun designs, the G2 collects a relatively large amount of current. Check with the cathode ray tube manufacturer on G2 supply impedance.

The bias voltage should be well regulated to eliminate unwanted modulation of the beam current. In some cases, it is also advisable to use dc on the filament. Care should be exercised in modulating the cathode itself since a defocusing action is experienced on the phosphor screen due to the apparent change of distance u Figure 2.

The Focus Coil and Focus Supply

For best resolution, a high quality focus coil is required. Also, since the focus is a function of the current flowing through the coil, a well regulated current supply which matches the coil should be employed. It is further important that the coil be properly aligned for optimum spot size over the entire screen area. Good regulation and alignment is also required for electrostatic focus tubes. Note that alignment can not be readily adjusted after tube assembly for an electrostatic lens which is inside the cathode ray tube envelope.

There is a running argument in the industry on the relative merits of electrostatic vs. electromagnetic focus. Theoretically at least, electromagnetic focus is better, especially for higher current applications. On the other hand, electrostatic focus appears simpler and is favored where there is a high sensitivity to volume and weight.

The Deflection Coil and Deflection Amplifier

Although change in beam path length is the major contributor to deflection defocusing, it is also true that in many cases, poor resolution can be traced to non-uniformities in the deflecting fields. Thus, as was previous mentioned, only high quality deflection yokes should be used. The deflecting fields themselves can introduce astigmatism which is difficult to correct for, without a dynamic astigmatism corrector. It is reported to be more difficult for the deflection coil manufacturers to hold field uniformity with lower inductance yokes. It would thus appear that there is a trade-off in this respect between speed and resolution.

The trade-off which is possible between deflection power and resolution has been previously pointed out. It is also advisable to eliminate any hum in the deflection circuitry which can wobble the beam with the result of an apparently large spot size.

It is generally conceded that electromagnetic deflection is superior to electrostatic deflection for high resolution applications. This is so mainly because of the small deflection angles required for electrostatic deflection thus placing the focusing element further from the screen, the lower anode voltages required, and the non-uniformity of the fields in the electrostatic deflection region.

Since high resolution cathode ray tube screens are easily burned,[11] it is wise to provide some form of sweep failure protection.

[11] *W. R. Elliot*, Limitations on High Energy Cathode Ray Tube Beams With Regard to Phosphor Life. *6th National Symposium, Society for Information Display.*

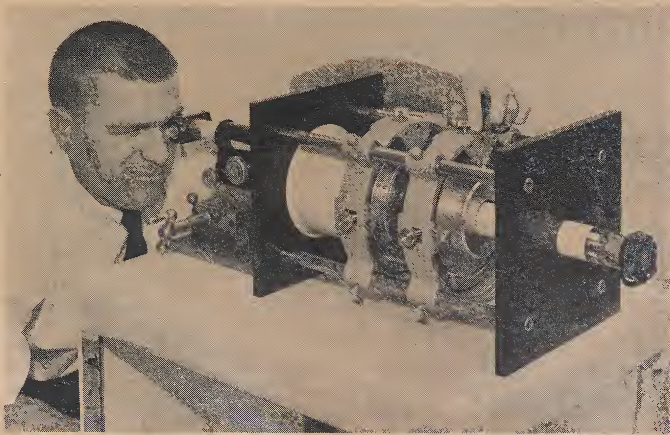

FIGURE 4: Aligning a high resolution cathode ray tube using a microscope.

Mechanical Equipment

In order to achieve minimum spot size, the electrical center of the focus coil and deflection yoke must coincide with the electrical center of the tube. The electrical centers and the mechanical centers of the coils and tubes are not necessarily coincident. The author, shown in Figure 4, is seen following the procedure described in the following material.

A relatively simple procedure will allow alignment of the electrical centers of the coils with the tube. This procedure calls for the ability to move the coils in a precise way with respect to the tube. The tube should be firmly fixed in a mount which also holds the focus coil and deflection coil. The method of holding the coils should be such that the coils can be adjusted in X translation, Y translation, pitch and yaw separately. Means of rotational and longitudinal adjustment is also a desirable feature.

It is essential that there should be no unwanted movement or vibration of the coils with respect to the tube while the tube is operating. This may cause spot wobble which will degrade resolution. Instructions for aligning the coils are available from tube and coil manufacturers.

A magnetic shield is another essential for high resolution displays. This is especially true if the tube is in an area where there are transformers or solenoids nearby. It takes only a very small movement (due to stray magnetic fields) to wobble a 0.001 in. beam to a 0.0015 in. beam, a change in resolution of 50%.

Some high resolution tubes today require a centering magnet or coil. Tubes which employ an aperture in the G3 barrel (see Figure 2) to achieve small spot size require a centering device to center the beam in the aperture. The centering device also centers the beam on the phosphor screen prior to alignment. Generally, it is desirable to avoid the use of a centering device since the magnetic field can introduce astigmatism on the beam. Electromagnetic centering coils are available which are reported to have a lesser effect on the beam uniformity.

The intrinsic, unfocused, undeflected, spot landing position on a typical 5 in, 40° tube is within a 5 mm radius from the mechanical center of the screen. The reason for the variation in spot landing position is that, as pointed out before, the electrical center and mechanical center of the tube do not necessarily coincide.

Most manufacturers will supply tubes with closer spot landing specifications for a premium. If a centering magnetic or coil must be used, some manufacturers require the magnet to be used over the gun, and some do not. There does not seem to be a hard and fast rule in this respect and the best advice is to do that which gets the required result.

Equipment for Fiber Optic Tubes

A special note is in order regarding fiber optic tubes. Each interstitial space between fibers on fiber optic plates is a potential weak point electrically speaking. That is, if a large voltage potential is placed across the plate as would be the case on a cathode ray tube, there may be an arc through the faceplate which will destroy the tube.

Because of this, fiber optic tubes should be run grounded anode. In many cases, grounded anode operation is convenient anyway, since it allows one to put his hands around the face of the tube without danger of shock; it reduces dust collection and facilitates coupling to the auxiliary plates on dual deflection tube types.

Video can be fed to the electron gun at the high negative potential through an rf coupling, a light diode coupler, or a coupling capacitor; the latter being the least desirable approach because of energy storage and poor dc response.

Stability

If careful attention is devoted to mounting configuration and power supply stability, the only remaining stability problem is a possible drift in amount of beam current caused by heating and subsequent shifting of the gun elements. If the system requires a steady light output and does not employ automatic brightness control, [12] it may be well to discuss drift with the prospective tube supplier.

Packaging

A trend in high resolution cathode ray tube applications today is toward the integrated tube package where the cathode ray tube, deflection yoke and focus coil are prealigned with the tube and potted inside a magnetic shield.

Some tubes are available with an intrinsic mounting ring on the face which is drilled and taped so the tube may be bolted into the optical system. The surfaces on the mounting ring are machined in such a way that when the tube is bolted in place, perpendicularity and concentricity of the faceplate to the center line of the optical system is assured.

The potted package is particularly popular in military systems. Other techniques are incorporated which prevent gun movement while undergoing shock and vibration.

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